PERFORMANCE EVALUATION OF A 33 MEGAPIXEL ALPA 12 MEDIUM FORMAT CAMERA FOR DIGITAL CLOSE RANGE PHOTOGRAMMETRY

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ABSTRACT:

The accuracy of object reconstruction was tested with two medium format cameras made by ALPA of Switzerland. Both cameras have been equipped with a 33 megapixel Leaf Aptus 75 digital camera back and a 47 mm focal length Schneider Apo-Digitar lens. The first test was carried out with the lens in “normal” position. In the second test, the principal point of another Apo-Digitar lens type was decentred by a fixed amount of approximately 8 mm. Decentring the principal point of a lens can be of advantage for terrestrial applications. Both cameras reveal large accuracy of object reconstruction, checked against calibrated scale bars in a test field (according to VDI/VDE Guideline 2634). The accuracy of object reconstruction of the camera system with the decentred lens does not reach the same level as for the “normal” camera.

1. INTRODUCTION

1.1 Digital cameras

In recent years, digital image acquisition in close-range photogrammetry has relied mostly on cameras that are not specifically designed for this application. This means that any newly introduced digital camera is a potential measurement tool for photogrammetrists. While many new and sophisticated features have been added to modern cameras – autofocus, zoom lenses, retrofocus constructions, image stabilizers, among many others – most of theses features are not very useful to photogrammetrists, or might even reduce the potential accuracy of a given camera. Photogrammetrists have such great demands on the optical and mechanical quality and stability of digital cameras that they can hardly be met by standard photographic equipment.

In order to make standard cameras suitable for photogrammetric work, they often require mechanical changes to improve stability of the system, or involve extended numerical models for camera calibration. Most suitable for such adaptations are cameras that provide the least amount of systematic image errors, and employ good stability of the system prior to any modification.

In this report, we investigate the ALPA 12 TC with two different types of 47 mm Schneider Apo-Digitar lenses. In combination with a digital camera back and a lens optimized for digital photography, this camera fulfils the basic requirements that can be asked for by photogrammetrists in the beginning.

1.2 The ALPA 12 TC camera system

The ALPA 12 TC is the core module of an image acquisition system (Fig. 1). Both sides of the camera can be used interchangeably to attach a lens or a camera back via a clamp mechanism. The quadratic mount allows attaching lens and back in 90 degree steps. Film and digital camera backs of several camera manufacturers up to a film format of 6 by 9 cm² can be fitted on the ALPA. The maximum image area is 84 by 84 mm². The ALPA 12 TC is the most compact ALPA camera. The camera frame weighs 218 g, total weight of camera, lens, viewfinder, and digital back with battery is 1550 g. The assembled camera exhibits three clamped connections at the interface lens board to camera, camera to back adapter, and back adapter to camera back.

1.3 The lenses

Two Schneider Apo-Digitar lenses with a nominal focal length of 47 mm were utilized in the tests. The Apo-Digitar lens series is especially designed to meet the high demands of digital image sensors regarding image resolution as well as colour fringing, and other aberrations. The symmetric design of the lens elements assures small values for radial symmetric lens distortion. The lens was tested in two different versions. The first test was carried out with a “normal“ 47 mm lens where the principal point coincides approximately with the centre of the image sensor. The second test was performed with the same kind of lens which had a fixed displacement of the principal point of approximately 8 mm (Fig. 1). The sensor in the Leaf Aptus 75 digital back requires a lens with an image circle of at least 60 mm. Since the 47 mm Schneider employs an image circle of 113 mm (for an aperture reading of 11), the lens not necessarily has to be centred in front of the sensor, but may be decentred. The maximum fixed shift that can be accomplished on the ALPA lens board is 8 mm. With the shift spiral mechanism of the ALPA 12 SWA camera, the whole lens board can be shifted up to 25 mm. Decentring of lenses with large image circles in front of the sensor by a fixed or an adjustable amount is a specialty of ALPA which allows photographers as well as photogrammetrists to optimize their camera for terrestrial applications. Similar lenses were utilized in the past

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in terrestrial photogrammetric cameras like the Wild P31 and P32. Possible applications for a digital camera with decentred or shifted principal point have been summarised by Rieke-Zapp (2006).

Figure 1. ALPA 12 TC with decentred Schneider Apo-Digitar and Leaf Aptus 75 digital camera back.

1.4 Digital camera back

The Leaf Aptus 75 is a 33 megapixel CCD (charged coupled device) digital camera back with dimensions of 48 by 36 mm² (6726 by 5040 pixel). Pixel spacing is approximately 7.1 µm. The back is powered by a replaceable battery; images are stored on compact flash cards. Images were saved as raw data and converted to the tagged image file format (tiff) with Leaf software without sharpening and all other parameters also set to zero.

2. EXPERIMENTAL SETUP

2.1 Testfield

Guidelines for certification and control of photogrammetric 3D measurement systems have been compiled in the German VDI/VDE guideline 2634, Part 1 "Optical 3D measuring systems – Optical systems based on point-by-point probing" (Luhmann and Wendt, 2000; VDI/VDE, 2002). This authoritative German standard applies to mobile 3D measurement systems comprising one or more cameras and a desktop or mobile computer with software for image measurement, orientation, and 3D object reconstruction. The procedure is based upon the photogrammetric survey of a spatial testfield with target points placed along a minimum of seven measuring lines. At least five calibrated distances are placed on each measuring line. The calibrated length between signalized points is compared with the distances calculated by photogrammetric means. The differences between measured and calibrated length are the length measurement errors. The maximum permitted length measurement error in the calibration volume is the criterion for the quality of the calibrated measurement system. Further details regarding the setup of the testfield and the execution of the measurements can be found in the VDI/VDE standard (VDI/VDE, 2002).

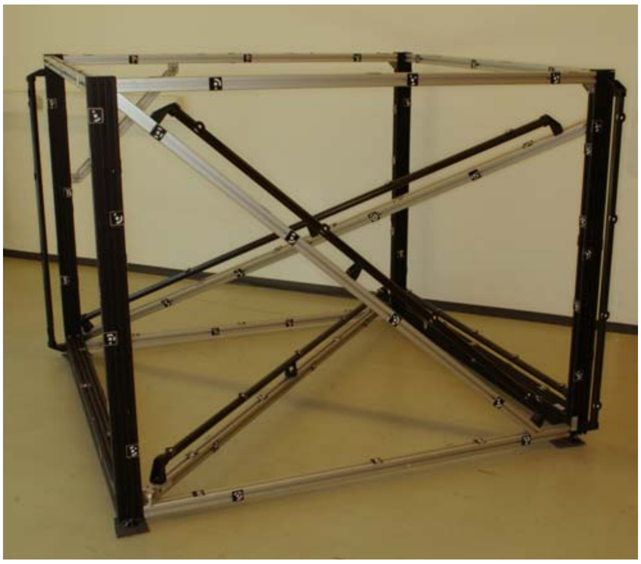

Figure 2. Testfield

The testfield that was used for the study presented here contains 173 retro-reflective circular target points, 33 of which were placed on seven calibrated scale bars. The length measurement errors are based on 58 calibrated distances.

2.2 Image acquisition and analysis

The camera was equipped with a ring flash for image capture. This allowed hand held use of the camera and quick movement around the object. The lens was stopped down to f/16. Images were acquired from stand points all around the testfield, taking photos from three different heights. 85 and 93 images were used in the bundle block adjustment with the normal and the decentred lens, respectively. The camera was rotated about the optical axis several times to assure correct determination of the parameters of interior orientation. The focussing ring was fixed with tape. The calibration was calculated with 3D Studio bundle block-adjustment software by AICON 3D Systems. The average image scale was approximately 1: 90. The system was scaled with a single distance on a scale bar that was placed in the centre of the test volume.

3. RESULTS AND DISCUSSION

3.1 Results

For both tests the parameters of the interior orientation (camera constant, coordinates of the principal point), radial-symmetric and decentering lens distortion, were calculated in a bundle block adjustment. Affinity and shear resulted only in a negligible improvement on the length measurement error and were therefore not introduced in the calibration procedure. Camera constant and the position of the principal point changed significantly between images in this simultaneous calibration (Table 1). Therefore, the adjustment was calculated with varying interior orientation of the images.

ALPA 12 TC	Sigma0 [mm]	Mean c† range [mm]	Mean xh‡ range [mm]	Mean yh# range [mm]
w/o Shift	0.00038	48.236 0.050	0.198 0.192	-0.065 0.184
with Shift	0.00051	48.461 0.071	0.382 0.141	-7.992 0.193

†focal length; ‡x- and #y- co-ordinate of principal point

ALPA 12 TC	Max positive deviation [mm]	Max negative deviation [mm]	Range [mm]
w/o Shift	0.056	-0.051	0.107
with Shift	0.057	-0.070	0.127

Table 1. Results of camera calibration

The position of the principal point ranged up to 0.192 and 0.193 mm (±13 pixel), the camera constant ranged by 0.050 mm and 0.071 mm (±5 pixel) for the camera without and with decentred lens, respectively (Table 1). The most significant variations were observed when the camera was rotated around the optical axis.

3.2 Discussion

Superimposing the distortion graphs from the two different lenses reveals a close match of both graphs (Fig. 3). The maximum radial-symmetric distortion in the corner of the image was less than 0.1 mm for the lens with centred principal point and less than 0.15 mm for the lens with decentred principal point. The asymmetric coverage of the sensor in case of the decentred lens results in a larger maximum radial distance than for the other case. The very good impression of image quality is reflected in the precision of image measurements (σ_0) of up to 0.38 µm or approximately 0.05 pixels (Table 1). Only little systematic image errors are present considering that the diagonal angle of view of the lens is 65° and 73° degrees corresponding to the maximum radial distance from the principal points, for the normal and the decentred lens, respectively. The standard deviations of the object coordinates amount to sX = 0.011 mm, sY = 0.009 mm and sZ = 0.011mm after the bundle adjustment (interior accuracy) for the system with the lens in "normal" position.

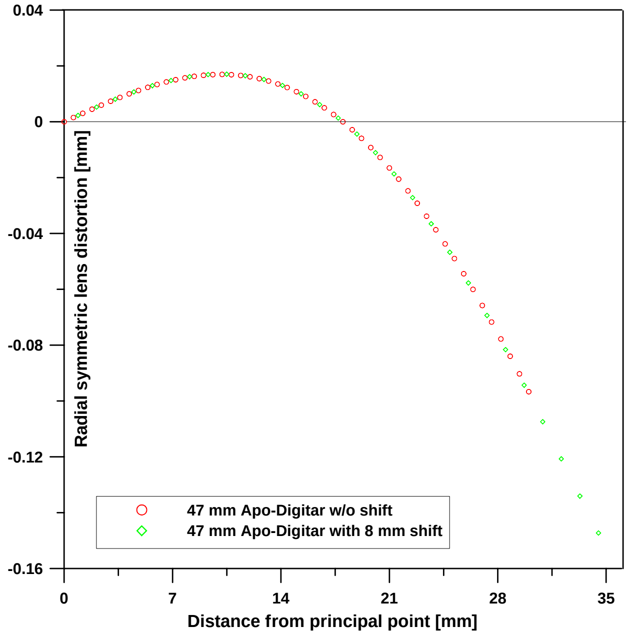

Figure 3. Radial symmetric lens distortion for both 47 mm Schneider Apo-Digitar lenses

The length measurement errors range within 0.107 and 0.127 mm which is a favourable result, but does not surpass results accomplished in similar tests with cameras that have a smaller pixel count and lower cost (Peipe and Yu, 2004). The bundle block adjustment produced meaningful calibration results for both cameras. Distortion graphs are very similar and additional tests have shown that the position of the principal point was calculated correctly even in the case of the decentred lens. The resulting precision of image measurements (σ_0) as well as the length measurement accuracy of the decentred version of the camera fall slightly short compared to the results accomplished in the case where the lens was in the in normal position. This may be attributed to the asymmetric coverage of the sensor by the decentred lens, resulting in a more one-sided distribution of image measurements.

The variability of the position of the principal point may be attributed to the number of camera components clamped to one system for image acquisition. This mechanism is not optimum for photogrammetric use, leaving some room for improvement. This result is typical for medium format cameras with interchangeable backs. The mounting of the camera back is an additional source for instability (Rieke-Zapp et al., 2005).

4. CONCLUSIONS AND OUTLOOK

The ALPA 12 TC camera is able to produce a length measurement accuracy of approximately 0.1 mm using a test arrangement corresponding to the VDI/VDE 2634 guideline. This accuracy is similar to results obtained with high resolution

SLR cameras like the Nikon D2X that have a smaller pixel count and also cost less.

Decentring the principal point is a rare feature for a digital camera system. Working with a displaced principal point can be of great advantage for terrestrial applications and for special purposes. The asymmetric coverage of the image sensor and the extreme image angle of view on one side of the sensor result in a reduction of length measurement accuracy by approximately 18% which will reduce the usefulness for high-precision applications.

At the moment, the photogrammetric accuracy potential of the camera can not be utilized to the fullest extent. Fixation of the connections between lens, camera and sensor should lead to better results.

5. REFERENCES

Luhmann, T., and K. Wendt, 2000. Recommendations for an acceptance and verification test of optical 3D measurement systems. *International Archives of Photogrammetry and Remote Sensing,* 33(B5), pp. 493-499.

Peipe, J., and Q. Yu, 2004. Wie viele Pixel braucht der Mensch? Kameras und ihre Anwendung. *Photogrammetrie - Laserscanning - Optische 3D-Messtechnik, Beiträge der Oldenburger 3D-Tage 2004* (Ed. T. Luhmann), pp. 116-123.

Rieke-Zapp, D., A. Oldani, and J. Peipe, 2005. Eine neue, hochauflösende Mittelformatkamera für die digitale Nahbereichsphotogrammetrie. *Publikationen der Deutschen Gesellschaft für Photogrammetrie und Fernerkundung (14)*, (Ed. E. Seyfried), pp. 263-270.

Rieke-Zapp, D. H., 2006. Wenn's etwas mehr sein darf: Verschieben der Hauptpunklage für eine optimale Stereoabdeckung. *Photogrammetrie - Laserscanning - Optische 3D Messtechnik, Beiträge der Oldenburger 3D-Tage 2006* (Ed. T. Luhmann, and Ch. Müller), pp 32-39.

VDI/VDE, 2002. VDI/VDE Guideline 2634 Part 1, Optical 3D measuring systems – Imaging systems with point-by-point probing. Beuth Verlag, Berlin.

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